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(12) **United States Patent**
Bouton

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(54) **WIRELESS AND POWER-SOURCE-FREE
EXTRAVASATION AND INFILTRATION
DETECTION SENSOR**

(58) **Field of Classification Search**
CPC ... A61B 5/0507; A61B 5/7246; A61B 5/7203;
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(Continued)

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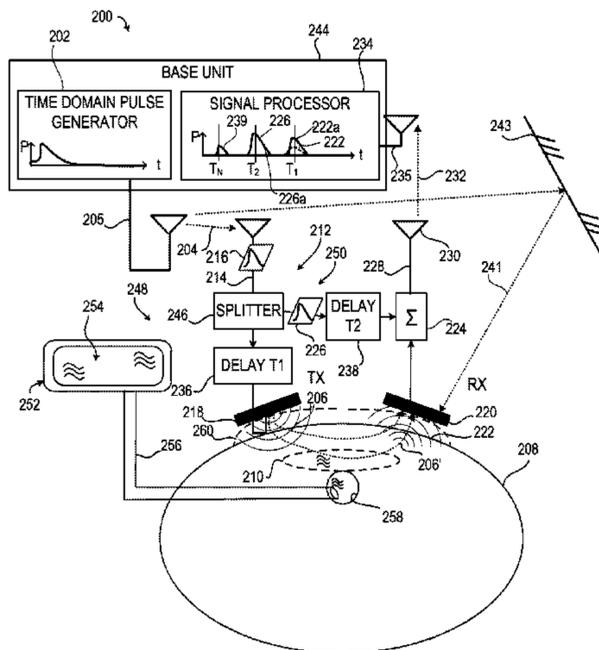
(57) **ABSTRACT**

(51) **Int. Cl.**
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A system detects extravasation or infiltration by segregating
active components that drive a passive sensor for economi-
cal single use. A receiving antenna of the passive sensor
receives a transmitted signal comprising RF electromagnetic
power. A first circuit transmits a first portion of the received
signal through a body portion. A sensor detects a resultant
signal from the body portion. A second circuit combines a
reference signal comprising a second portion of the received
signal with the resultant signal so as to define an output
signal. A transmit antenna transmits the output signal to a
receiver.

(52) **U.S. Cl.**
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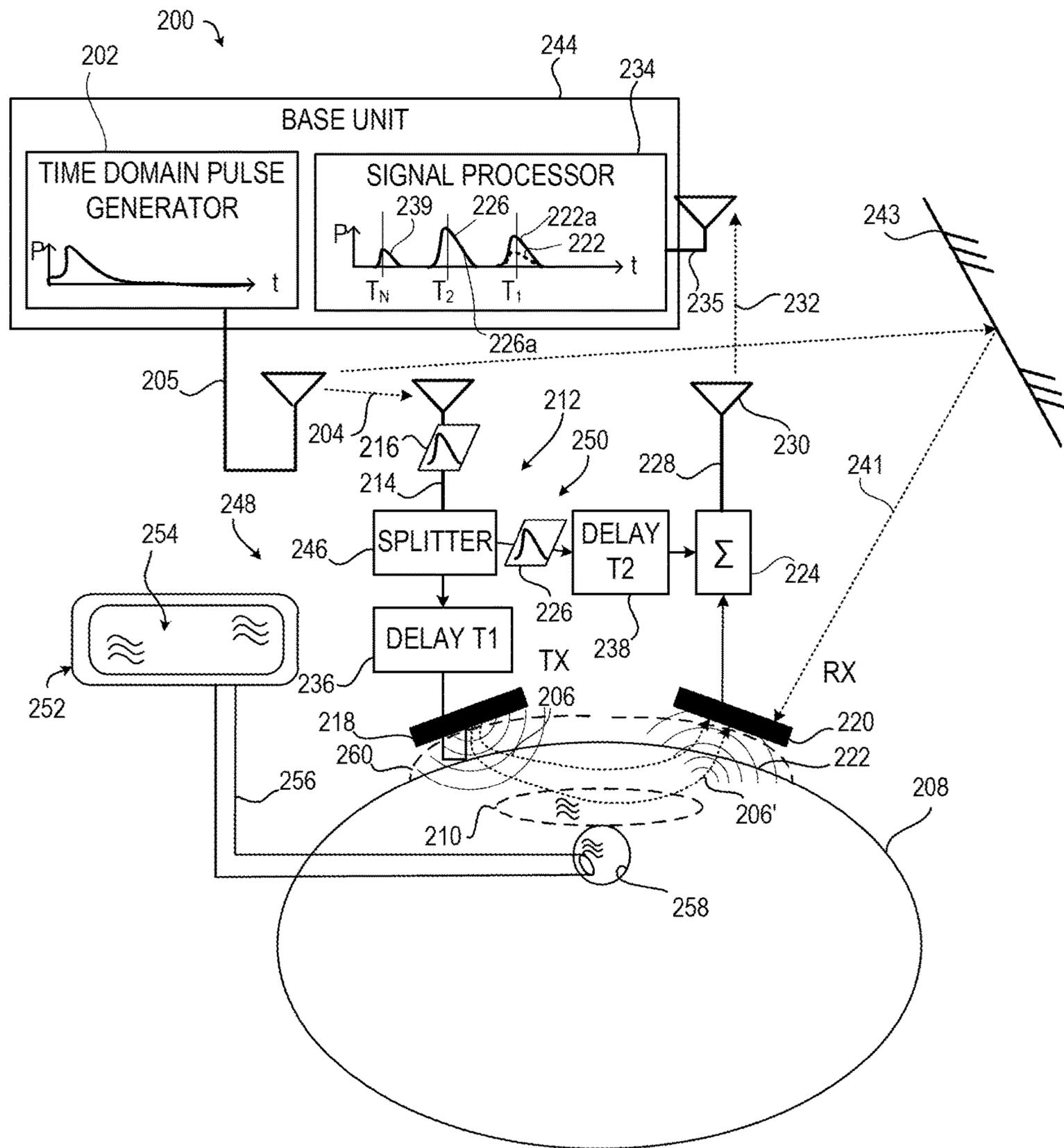
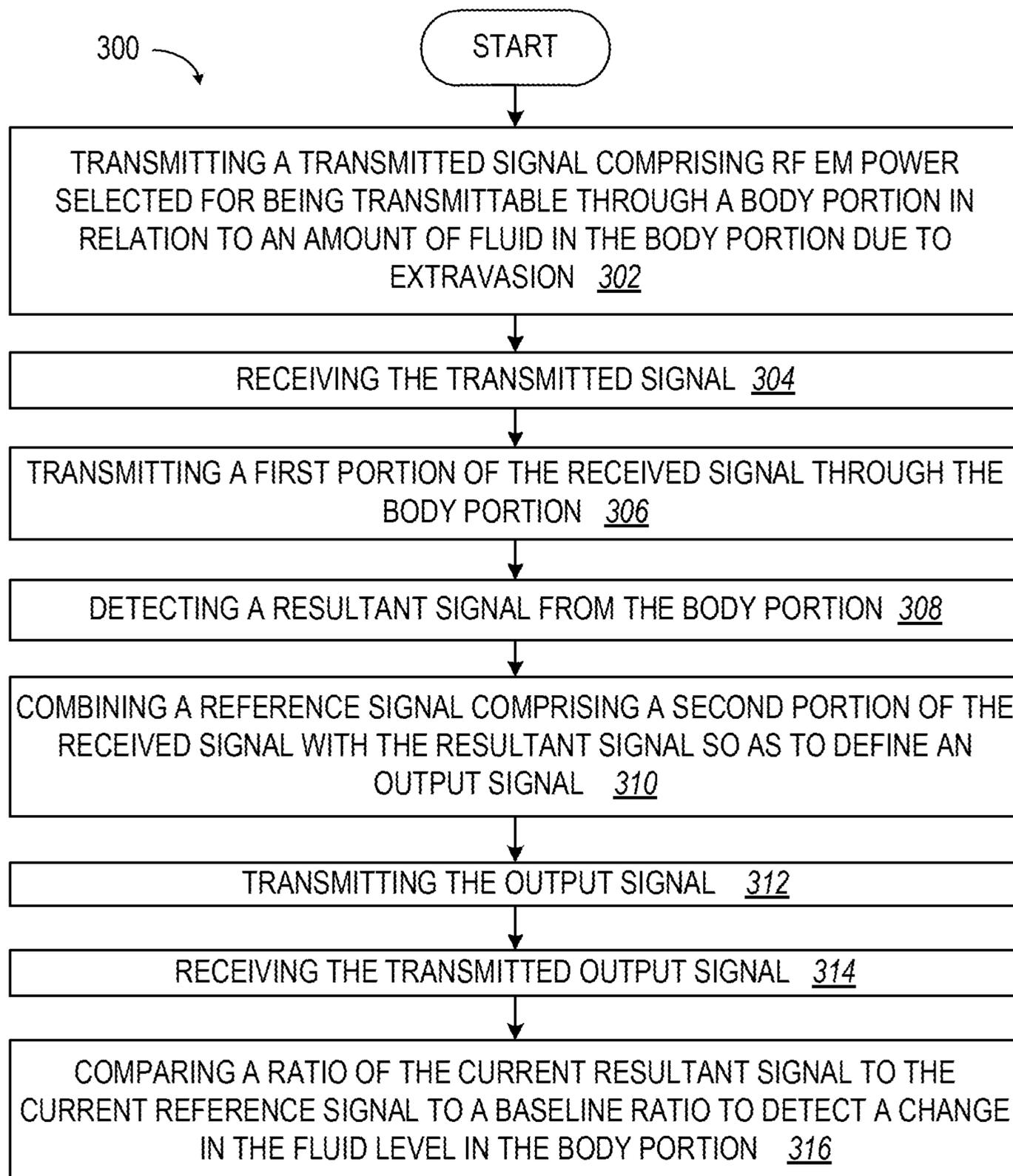


FIG. 2

**FIG. 3**

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**WIRELESS AND POWER-SOURCE-FREE
EXTRAVASATION AND INFILTRATION
DETECTION SENSOR**

TECHNICAL FIELD

The present invention relates generally to the detection of fluids in tissue, and, more particularly, to apparatuses, systems and methods for detection of changed, elevated or abnormal fluid levels in tissue.

BACKGROUND ART

Changed, elevated or abnormal fluid levels in living tissue can result from a number of physiological conditions. For example, edema is an abnormal accumulation of watery fluid in the intercellular spaces of connective tissue. Edematous tissues are swollen and, when punctured, secrete a thin incoagulable fluid. Edema is most frequently a symptom of disease rather than a disease in itself, and it may have a number of causes, most of which can be traced back to gross variations in the physiological mechanisms that normally maintain a constant water balance in the cells, tissues, and blood. Among the causes may be diseases of the kidneys, heart, veins, or lymphatic system; malnutrition; or allergic reactions.

Moreover, bleeding (hemorrhage) can cause blood to collect and clot (hematoma). Hematomas can, for example, occur beneath the outermost of three membranes that cover the brain (meninges) as a result of a head injury. There are two types of cranial subdural hematomas. An acute subdural hematoma occurs soon after a severe head injury. A chronic subdural hematoma is a complication that may develop weeks after a head injury. Such a head injury may have been so minor that the patient does not remember it. An epidural hematoma is a traumatic accumulation of blood between the inner table of the skull and the stripped-off dural membrane. The inciting event often is a focused blow to the head. It is often difficult to detect hematomas, particularly when the hematoma occurs well after the time of an injury.

In addition to accumulation of body fluids, elevated fluid levels in tissue can arise as a result of introduction of a fluid into the body, for example, during an injection procedure. In that regard, in many medical diagnostic and therapeutic procedures, a physician or other person injects fluid into a patient's blood vessels. Moreover, in recent years, a number of injector-actuated syringes and powered injectors for pressurized injection of contrast medium in procedures such as angiography, computed tomography, ultrasound and NMR/MRI (Nuclear Magnetic Resonance/Magnetic Resonance Imaging) have been developed.

Extravasation or infiltration is the accidental infusion or leakage of an injection fluid such as a contrast medium or a therapeutic agent into tissue surrounding a blood vessel rather than into the blood vessel itself. Extravasation can be caused, for example, by rupture or dissection of fragile vasculature, valve disease, inappropriate needle placement, or patient movement resulting in the infusing needle being pulled from the intended vessel or causing the needle to be pushed through the wall of the vessel. High injection pressures and/or rates of some modern procedures can increase the risk of extravasation. In computed tomography, for example, contrast injection flow rates can be in the range of 0.1 to 10 ml/s.

Extravasation can cause serious injury to patients. In that regard, certain injection fluids such as contrast media or chemotherapy drugs can be toxic to tissue. It is, therefore,

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very important when performing fluid injections to detect extravasation as soon as possible and discontinue the injection upon detection.

In U.S. Pat. No. 7,122,012 to Bouton, et al., issued Oct. 17, 2006, which is hereby incorporated by reference in its entirety, a method was disclosed for detecting a change in the level of fluid in tissue in a first area of a body. Steps included applying electromagnetic energy, preferably in the frequency range of approximately 300 MHz to approximately 30 GHz, to a first volume of the body; measuring a resultant or returned signal; comparing the signal to a reference signal to determine if the fluid level in the tissue has changed. In one embodiment, the method detected changes in the level of fluid in tissue of a body by applying electromagnetic energy to a first volume of the body over a period of time; measuring a resultant signal or a signal returned from the tissue; and comparing the signal to a reference signal to determine if a level of fluid in the tissue has changed during the period of time.

DISCLOSURE OF INVENTION

The following presents a summary in order to provide a basic understanding of some aspects of the disclosed aspects. This summary is not an extensive overview and is intended to neither identify key or critical elements nor delineate the scope of such aspects. Its purpose is to present some concepts of the described features in a form as a prelude to the more detailed description that is presented later.

In accordance with one or more aspects and embodiments, and the corresponding disclosures thereof, various features of the invention are described in connection with a wireless and passive sensor (no local power source is required on the sensor) of a system for detecting extravasation or infiltration. By segregating active components that drive the passive sensor via Radio Frequency (RF) transmission, the passive sensor can be economically disposed of after use. Thereby, health protocols in an institutional setting can be enhanced. Moreover, the passive sensor allows a degree of mobility for a wearer by being linked via the RF transmission.

In a first aspect, the present invention provides a passive sensor that comprises a receiving antenna for receiving a transmitted signal comprising RF electromagnetic power as a received signal. A first circuit transmits a first portion of the received signal through a body portion. A sensor detects a resultant signal from the body portion. A second portion of the received signal defining a reference signal passes through a reference pathway that is not affected by fluid or other changes in the tissue. The combination of the signal that has passed through the body portion, i.e., the resultant signal and the reference signal defines an output signal. A transmit antenna transmits the output signal to a receiver for use in determining a change in a level of fluid in the body portion.

In a second aspect, the present invention provides a system for detecting extravasation that comprises a sensor according to the first aspect of the invention. In some embodiments, the system of the invention may comprise a signal generator for transmitting a transmitted signal comprising RF electromagnetic power selected for being transmittable through a body portion in relation to an amount of fluid in the body portion due to extravasation. A passive sensor comprises a receiving antenna for receiving the transmitted signal as a received signal, a first circuit for transmitting a first portion of the received signal through the

body portion, a sensor for detecting a resultant signal from the body portion, a second circuit for combining a reference signal comprising a second portion of the received signal with the resultant signal so as to define an output signal, and a transmit antenna for transmitting the output signal. A signal processor may then receive the transmitted output signal for use in determining a change in fluid level in the body portion.

In some embodiments, the signal processor further performs a ratio comparison of peak amplitude of the resultant signal and the reference signal of the transmitted output signal.

In other embodiments, the signal generator may use a series of time domain pulses of electromagnetic power. The passive sensor may further comprises a first delay circuit for delaying a selected one of the first portion of the received signal comprising the time domain pulse and the second portion of the received signal comprising the time domain pulse as the reference signal. In a particularly suitable embodiment, a second delay circuit delays the other one of the first portion and the second portion of the time domain pulse. The first and second delay circuits may be configured to separate in time the resultant signal and the reference signal from each other as well as a noise pulse at the sensor arising due to a reflected portion of the transmitted signal.

In further embodiments, the receiving antenna further receives the transmitted signal predominantly in a range of greater than 1.5 GHz to approximately 30 GHz over a period of time. In a particular aspect, the range is less than 10 GHz.

In some embodiments, the transmitted signal may comprise a sweep of continuous wave electromagnetic power across a frequency range.

In further embodiments, a substrate is provided to support one or more, and suitable each of the receiving antenna, the first circuit for transmitting, the second circuit for combining, the sensor, and the transmit antenna.

In a third aspect, the present disclosure provides a method for detecting extravasation. A transmitted signal is transmitted comprising RF electromagnetic power selected for being transmittable through a body portion in relation to an amount of fluid in the body portion due to extravasation. The transmitted signal is received as a received signal. A first portion of the received signal is transmitted through the body portion. A resultant signal is detected from the body portion. A reference signal comprising a second portion of the received signal is combined with the resultant signal so as to define an output signal. The output signal is transmitted. The transmitted output signal is received. The output signal is used to determine a change in fluid level in the body portion. In a particularly suitable embodiment of this aspect, the method may be performed using a device, apparatus / system according to the invention.

In some embodiments, a ratio comparison of peak amplitude of the resultant signal and the reference signal is performed.

In another embodiment, the transmitted signal may further comprise a time domain pulse of electromagnetic power. The method further may further comprise delaying a selected one of the first portion of the received signal comprising the time domain pulse and a second portion of the received signal comprising the time domain pulse as the reference signal. The reference signal is combined with the resultant signal as pulses separated as a function of time. In a particularly suitable embodiments, the other one of the first portion and the second portion of the time domain pulse is delayed to separate in time the resultant signal and the reference signal from each other as well as blanking a noise

pulse arising due to a reflected portion of the transmitted signal from an ambient environment.

In an additional embodiment, the transmitted signal may be transmitted in a range of greater than 1.5 GHz to approximately 30 GHz over a period of time. In a particularly embodiment, the range is less than 10 GHz.

To the accomplishment of the foregoing and related ends, one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative aspects and are indicative of but a few of the various ways in which the principles of the aspects may be employed. Other advantages and novel features will become apparent from the following detailed description when considered in conjunction with the drawings and the disclosed aspects are intended to include all such aspects and their equivalents.

BRIEF DESCRIPTION OF DRAWINGS

The disclosed aspects will hereinafter be described in conjunction with the appended drawings, provided to illustrate and not to limit the disclosed aspects, wherein like designations denote like elements, and in which:

FIG. 1 is a schematic block diagram of a system for detecting a change in a fluid level in tissue using an RF driven passive sensor, according to one aspect;

FIG. 2 is a schematic block diagram of a system for detecting a change in a fluid level using a time-domain RF pulse with combined and transmitted time-delayed reference and resultant signals for remote signal processing, according to one aspect; and

FIG. 3 is a flow diagram of a methodology for detecting a change in the fluid level of tissue, according to one aspect.

MODES FOR CARRYING OUT THE INVENTION

While the sensors, systems and methods of the present invention are generally applicable to the sensing of a wide range of fluids within a variety of body tissues (whether a body fluid or an introduced fluid), the present invention is primarily described herein with reference to the representative example of extravasation of a fluid intended to be injected into a vascular structure. However, one skilled in the art with the benefit of the present disclosure can appreciate that elevated, abnormal or changing levels of generally any fluid can be detected using the sensors, systems and methods of the present invention. Detection of body fluids in the present invention includes, but is not limited to, the detection of fluid changes as a result of edema, hematoma, ruptured bowel and colostomy tubing leakage into the peritoneal cavity. Introduced or foreign fluid detectable in the present invention include fluid introduced via generally any technique known in the medical arts including, but not limited to, injection, infusion and IV drip. Changes in complex permittivity and permeability as a result of changing fluid levels in tissue are detected by application of electromagnetic power to the tissue and detection of a resultant signal.

Complex permittivity and permeability govern how an electromagnetic wave will propagate through a substance. Complex permittivity typically has the greatest effect since it varies significantly between tissue types and fluids of interest. The complex permeability of various tissues and many fluids of interest is approximately that of a vacuum, reducing the effect of this parameter. However, some fluids

such as MRI contrast agents may have an appreciable complex permeability difference from tissue. Although blood contains small amounts of iron, the permeability value for any significant volume of blood is typically insignificant. Complex permittivity is generally expressed as

$$\epsilon^* = \epsilon' - j\epsilon''$$

wherein ϵ' is the real component of the complex value and is known as the dielectric constant or sometimes simply referred to as the "permittivity." The term ϵ'' is the imaginary component of the complex value and is often referred to as the "loss factor." The ratio of ϵ''/ϵ' is known as the "loss tangent." The complex permittivity (and sometimes permeability) of certain substances differ from the body tissue at certain frequencies. In the present invention, such differences in permittivity and/or permeability are used for the detection and level monitoring of certain fluids and substances in biological tissue.

The studies of the present innovation have shown that electromagnetic power having, for example, a frequency in the range of approximately 300 MHz to approximately 30 GHz (and, more preferably, in the range of approximately 1 GHz to approximately 10 GHz, and, even more preferably, in the range of approximately 3 GHz to approximately 5 GHz to 10 GHz) provides good penetration into tissue. In general, such electromagnetic power is launched into the subcutaneous tissue and a resultant signal is measured. Electromagnetic power in the frequency range set forth above has been found to transmit through the skin and to transmit or propagate well within, for example, fat. Good transmission through the fat layer is beneficial for detection of extravasation as many extravasations occur in the fat layer. The sensitivity to extravasation of the systems, devices and methods of the present invention is thus increased as compared, for example, to impedance plethysmography. In the case of impedance plethysmography, the majority of the electrical current passes through highly conductive layers such as skin and muscle in which extravasation is much less likely to occur.

While using RF electromagnetic power to detect extravasation and infiltration has thus been established as an effective approach, the present innovation addresses certain clinical aspects. Fluid injections, liquid infusions, and IV drips require that measures be taken to avoid infection. In particular, tubing and dressings are typically disposable and frequently replaced. Sensing extravasation or infiltration can entail placement of transmitters and receivers close to an insertion point on the skin of a patient. As such, a device for detecting extravasation or infiltration of fluids in the tissue can pose as a source of infection or contamination if not similarly disposable. However, circuitry for generating and analyzing RF electromagnetic signals typically entails use of digital signal processing equipment that can prove to be too expensive for single uses.

Thus, a passive sensor of a system is driven by transmitted RF electromagnetic power, passes the power through tissue of a body portion for detecting a level of fluid, and transmits back an output signal for remote digital signal processing. Thereby, a relatively inexpensive component implementation can be incorporated into the passive sensor. In certain clinical environments, more than one passive sensor can be driven by the transmitted RF electromagnetic power since the transmission in response can be delayed in time as well as being at a reduced power level.

Various aspects are now described with reference to the drawings. In the following description, for purposes of explanation, numerous specific details are set forth in order

to provide a thorough understanding of one or more aspects. It may be evident, however, that such aspect(s) may be practiced without these specific details.

In FIG. 1, the present disclosure provides a system **100** for detecting extravasation or infiltration. A signal generator **102** transmits a transmitted signal **104** comprising Radio Frequency (RF) electromagnetic power selected for being transmittable as depicted at **106** or **106'** through a body portion **108** in relation to an amount of fluid **110** in the body portion **108** due to extravasation or infiltration.

A passive sensor **112** has a receiving antenna **114** for receiving the transmitted signal **104** as a received signal **116**. The transmitted signal is split via a conventional splitter (not shown) into first and second portions. A first circuit **118** transmits the first portion of the received signal **116** through the body portion **108**. A sensor **120** detects a resultant signal **122** from the body portion **108**. The second portion of the received signal **116** travels through a reference pathway such as a delay line, wherein the second portion of the received signal is not affected by fluid or other changes in the tissue. A second circuit **124** combines the reference signal **126** comprising the second portion of the received signal **116** with the resultant signal **122** so as to define an output signal **128**. A transmit antenna **130** transmits the output signal **128** as a transmitted output signal **132**.

A signal processor **134** receives the transmitted output signal **132** as a received signal and uses the output signal **132** to determine a change in the fluid level within the body portion **108**. In the illustrated embodiment, the signal processor compares a ratio of a peak amplitude of the resultant signal **122** to a peak amplitude of the reference signal **126**, which ratio is determined from the output signal **132** during fluid injection into a patient body portion **108**, with a ratio of a peak amplitude of a resultant signal to a peak amplitude of a reference signal taken earlier in time via the passive sensor **112** during a baseline detection operation, e.g., just before fluid is injected into the body portion **108**. In FIG. 1, a first portion **106** of the received signal **104** corresponds to a signal being transmitted through the body portion **108** during a baseline operation and a first portion **106'** of the received signal **104** corresponds to a signal being transmitted through the body portion **108** later in time when fluid has accumulated in the body portion **108** such that the first portion **106'** passes through the accumulated fluid in the body portion **108**.

In another aspect, the transmitted signal **104** further comprises a time domain pulse of electromagnetic power. The passive sensor **112** further comprises a first delay circuit **136** for delaying a selected one of the first portion of the received signal **116** comprising the time domain pulse and the second portion of the received signal comprising the time domain pulse as the reference signal **126**. The second circuit **124** further combines the reference signal **126** with the resultant signal **122** comprising pulses separated as a function of time by the first delay circuit **136**. In a particular aspect, a second delay circuit **138** delays the other one of the first portion and the second portion of the time domain pulse. The first and second delay circuits **136**, **138** are configured to separate in time the resultant signal **122** and the reference signal **126** from each other as well as a noise pulse at the sensor **120** arising due to a reflected portion of the transmitted signal **104**. Hence, there are two time delays for the first and second portions of the received signal **104**. First, the two time delays are intentionally longer than room reflection delays so that the resultant signal **122** and the reference signal **126** can be separated from the room reflections in a final processing step. Second, the delay along the tissue

pathway is intentionally different than the delay along the reference pathway, so that the resultant signal **122** and the reference signal **126** can be separated and analyzed. The delay along the reference pathway may be longer or shorter than the delay along the tissue pathway.

In another aspect, the receiving antenna **114** is further for receiving the transmitted signal **104** in a range of greater than 1.5 GHz to approximately 30 GHz over a period of time, and more particular the range is less than 10 GHz.

In an additional aspect, the passive sensor **112** includes a substrate **140** for supporting at least the receiving antenna **114**, the first circuit **118** for transmitting, the second circuit **124** for combining, the sensor **120**, and the transmit antenna **130**.

In an exemplary aspect in FIG. 2, a system **200** has a signal generator **202**, depicted as a time-domain pulse generator, that transmits a transmitted signal **204** as a time domain pulse via a transmit antenna(s) **205** to cause transmission as depicted at **206** or **206'** through a body portion **208** in relation to an amount of fluid **210** in the body portion **208** due to extravasation or infiltration.

To that end, a passive sensor **212** has a receiving (RX) antenna(s) **214** for receiving the transmitted signal **204** (time domain pulse) as a received pulse or received signal **216**. Thus, the passive sensor **212** comprises the RX antenna(s) **214** that receives a time domain impulse stream from a base unit **244** that includes the signal generator **202**. This base unit **244** uses time domain or ultra-wideband radar methods to generate a series of impulses to be sent to the passive sensor **212**. The passive sensor **212** then comprises a splitter **246** that splits first and second portions of the received signal **216** from the RX antenna(s) **214**, respectfully, to a pathway **248** that will include the tissue of interest for sensing fluid **210** and a pathway **250** that returns the second portion of the signal back to the base unit **244**.

A first circuit **218** comprising a transmit antenna(s) transmits the first portion of the received signal **216** through the body portion **208**. A sensor **220** comprising a receiving antenna(s) detects a resultant signal **222** from the body portion **208**. A second circuit **224** combines the second portion of the received signal **216**, which second portion defines a reference signal **226**, with the resultant signal **222** so as to define an output signal **228**. A transmit antenna(s) **230** transmits the output signal **228** as a transmitted output signal **232**.

A signal processor **234** serves as an extravasation/infiltration detector by receiving the transmitted output signal **232** at a receiving antenna(s) **235** as a received signal and for comparing a patient fluid injection ratio of the resultant signal **222** to the reference signal **226** taken during patient fluid injection to a baseline ratio of a resultant signal to a reference signal generated earlier in time during a baseline detection operation so as to detect a change from the baseline ratio, which change corresponds to a change in the fluid level in the body portion **208**. If the patient fluid injection ratio is less than a predefined percentage of the baseline ratio, e.g., 90% of the baseline ratio, then this can warrant an alert indicating that an unacceptable fluid level change has occurred. In FIG. 2, a first portion **206** of a received signal corresponds to a signal being transmitted through the body portion **208** during the baseline operation and a first portion **206'** of a received signal **204** corresponds to a signal being transmitted through the body portion **208** later in time when fluid **210** has accumulated in the body portion **208** such that the first portion **206'** passes through the accumulated fluid **210** in the body portion **208**.

In the exemplary implementation, the passive sensor **212** further comprises a first delay circuit **236** depicted as a delay line **T1**, for delaying the first portion of the received signal **216** by a time "T1" prior to transmission through the body portion **208** so as to ensure that the first portion lags the second portion of the received signal **216**. In a particular aspect, a second delay circuit **238** delays the reference signal **226** such that the reference signal **226** is separated in time, i.e., follows a noise pulse **239** at the sensor **220** arising due to a reflected portion **241** of the transmitted signal **204** from an ambient environment **243**, see FIG. 2. In the illustrated embodiment, time $T1+T_T$ (signal delay in a patient body portion) is greater than time **T2**. However, it is contemplated that time **T2** may be greater than $T1+T_T$.

Hence, both pathways **248**, **250** illustrated in FIG. 2 have first and second delay circuits **236**, **238** (delay line **T1** and delay line **T2**). The delay line **T1** (first delay circuit **236**) is present so that the signal that propagates through the tissue will lag behind the **T2** pathway signal. Delay line **T2** (second delay circuit **238**) allows room reflections to complete before the transmitted reference signal **226** is returned to the signal processor **234** of the base unit **244**. Thus, the shorter pathway provides the reference signal **226** that is independent of the tissue/fluid effects, but will include effects of distance changes between the passive sensor **212** and the base unit **244**. Thereby, the system **200** looks for relative changes between the ratio of the current resultant signal **222** to the current reference signal **226** to a baseline ratio of a resultant signal **222A** to a reference signal **226A** generated earlier in time during a baseline detection operation so as to detect a change from the baseline ratio, which change corresponds to a change in the fluid level in the body portion **208**. If the sensor **212** moves away from the base unit **244**, both the current resultant signal **222** and the current reference signal **226** will decrease by the same percentage such that the ratio remains constant. If a fluid accumulation occurs within the body portion **208**, the ratio of the current resultant signal **222** to the current reference signal **226** will change relative to the baseline ratio.

In use, a fluid supply **252** (e.g., infuser supply, contrast agent injector, IV drip, etc.) provides fluid **254** via a conduit **256** (e.g., catheter, needle, etc.) to a vascular body **258** of the body portion **208**. As depicted at **210**, extravasation or infiltration can cause an increase in a level of fluid that directly affects a signal **206'** propagating through the tissue, such as based in a change in permittivity. For example, if the current reference signal **226** during patient fluid injection equals the baseline reference signal **226A** and an increase in fluid level has occurred in the patient, then the current resultant signal **222** during patient fluid injection will typically be less than the baseline resultant signal **222A**, see FIG. 2. A resulting change in dimensions of the body portion **208**, as depicted at **260**, can cause a change in the signal **206'**.

In FIG. 3, a method **300** for detecting extravasation or infiltration is depicted. A transmitted signal is transmitted comprising RF electromagnetic power selected for being transmittable through a body portion in relation to an amount of fluid in the body portion due to extravasation or infiltration (block **302**). The transmitted signal is received as a received signal (block **304**). A first portion of the received signal is transmitted through the body portion (block **306**). A resultant signal is detected from the body portion (block **308**). A reference signal comprising a second portion of the received signal is combined with the resultant signal so as to define an output signal (block **310**). The output signal is transmitted (block **312**). The transmitted output signal is

received (block 314). A ratio of the current resultant signal to the current reference signal is compared to a baseline ratio to detect a change in the fluid level in the body portion (block 316).

In another exemplary aspect, the transmitted signal further comprises a time domain pulse of electromagnetic power. The method further comprises delaying a selected one of the first portion of the received signal comprising the time domain pulse and a second portion of the received signal comprising the time domain pulse as the reference signal. The reference signal is combined with the resultant signal as pulses separated as a function of time. In a particular aspect, the other one of the first portion and the second portion of the time domain pulse is delayed to separate in time the resultant signal and the reference signal from each other as well as blanking a noise pulse arising due to a reflected portion of the transmitted signal from an ambient environment.

In an additional exemplary aspect, the transmitted signal is transmitted in a range of greater than 1.5 GHz to approximately 30 GHz over a period of time. In a particular aspect, the range is less than 10 GHz.

In a further exemplary aspect, a user indication is presented of a selected one of an inoperative state, a nominal state and an extravasation state based upon the comparison.

In an alternative embodiment, the signal generator is a continuous wave (CW) source, which generates and transmits continuous wave power swept across a frequency range such as 2 GHz to 5 GHz (remaining at each frequency long enough for an amplitude and phase measurement by the receiving circuitry to be made, which is typically a fraction of a second). In the continuous wave embodiment, the passive sensor is generally the same as the passive sensor in the pulse source embodiment, discussed above. Hence, the passive sensor comprises a splitter for splitting continuous wave power into first and second portions, first and second delays for delaying (i.e., introducing differing phase shifts) the first and second portions different amounts, a first circuit comprising transmit and receive antennas and a second circuit for combining a resultant signal, which is defined by the second portion of the continuous wave power after passing through tissue, and a reference signal, which is defined by the first portion of the continuous wave power. Amplitude and phase data for a plurality of frequencies, e.g., 256 frequencies, of the combined signal are provided to a signal processor, which converts the frequency domain information from the combined signal into the time domain using inverse-Fourier or other transforms known in the art. Once in the time domain, the processor determines a first ratio of a peak amplitude of the resultant signal to a peak amplitude of the reference signal, which ratio is determined from the combined signal output during fluid injection into a patient body portion. The processor also determines a second ratio of a peak amplitude of a resultant signal to a peak amplitude of a reference signal taken earlier in time during a baseline detection operation, e.g., just before fluid is injected into the body portion. The processor then compares the first and second ratios to one another to detect a change in a fluid level in a body portion.

While the foregoing disclosure discusses illustrative aspects and/or embodiments, it should be noted that various changes and modifications could be made herein without departing from the scope of the described aspects and/or embodiments as defined by the appended claims. Furthermore, although elements of the described aspects and/or

explicitly stated. Additionally, all or a portion of any aspect and/or embodiment may be utilized with all or a portion of any other aspect and/or embodiment, unless stated otherwise.

It should be appreciated that any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated material does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure material set forth herein, will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

What is claimed is:

1. A system for detecting extravasation, comprising:
 - a signal generator for transmitting a transmitted signal comprising Radio Frequency (RF) electromagnetic power;
 - a passive sensor, comprising:
 - a receiving antenna configured to receive the transmitted signal as a received signal,
 - a first circuit configured to transmit only a first portion of the received signal through the body portion,
 - a sensor configured to detect a resultant signal from the body portion,
 - a second circuit configured to combine a reference signal comprising a second portion of the received signal with the resultant signal so as to define an output signal, and
 - a transmit antenna configured to transmit the output signal as a transmitted output signal; and
 - a signal processor configured to:
 - receive the transmitted output signal, and
 - perform a comparison of peak amplitude of resultant signal and the reference signal of the transmitted output signal to detect extravasation of fluid in the body portion by determining a change in fluid level in the body portion using the transmitted output signal,
- wherein the transmitted signal further comprises a time domain pulse of electromagnetic power, and
- wherein the passive sensor further comprises:
 - (i) a first delay circuit configured to delay a selected one of the first portion of the received signal comprising the time domain pulse and the second portion of the received signal comprising the time domain pulse as the reference signal, and
 - (ii) a second delay circuit configured to delay the other one of the first portion and the second portion of the time domain pulse, the first and second delay circuits being configured to separate in time the resultant signal, the reference signal, and a noise pulse at the sensor arising due to a reflected portion of the transmitted signal.
2. The system of claim 1, wherein the receiving antenna is further configured to receive the transmitted signal in a range of greater than 1.5 GHz to approximately 30 GHz over a period of time.
3. The system of claim 1, wherein the transmitted signal comprises a sweep of continuous wave electromagnetic power across a frequency range.

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4. The system of claim 1, further comprising a substrate configured to support said receiving antenna, said first circuit, said second circuit, said sensor, and said transmit antenna.

5. A method for detecting extravasation, comprising:
 transmitting, by a signal generator, a transmitted signal comprising Radio Frequency (RF) electromagnetic power;

received, by a receiving antenna of a passive sensor, the transmitted signal as a received signal;

transmitting, by a first circuit of the passive sensor, only a first portion of the received signal through a body portion;

detecting, by a sensor of the passive sensor, a resultant signal from the body portion;

combining, by a second circuit of the passive sensor, a reference signal comprising a second portion of the received signal with resultant signal to define an output signal;

transmitting, by a transmit antenna of the passive sensor, the output signal as a transmitted output signal;

receiving, by the signal processor, transmitted output signal;

performing, by the signal processor, a comparison of peak amplitude of the resultant signal and the reference signal; and

detecting, by signal processor, extravasation of fluid in the body portion by determining a change in fluid level in the body portion using the transmitted output signal, wherein the transmitted signal further comprises a time domain pulse of electromagnetic power, the method further comprising:

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delaying, by a first delay circuit of the passive sensor, a selected one of the first portion of the received signal comprising the time domain pulse and the second portion of the received signal comprising time domain pulse as the reference signal; and

delaying, by a second delay circuit of the passive sensor, the other one of the first portion and the second portion of the time domain pulse, wherein the first and second delay circuits are configured to separate in time the resultant signal, the reference signal, and a noise pulse at the sensor arising due to a reflected portion of the transmitted signal.

6. The method of claim 5, further comprising:

combining, by the second circuit of the passive sensor, the reference signal with the resultant signal as pulses separated as a function of time.

7. The method of claim 5, further comprising:

transmitting, by the signal generator, the transmitted signal in a range of greater than 1.5 GHz to approximately 30 GHz over a period of time.

8. The method of claim 5, wherein the transmitted signal comprises a pulse of continuous wave electromagnetic power across a frequency range.

9. The method of claim 5, wherein the reference signal is not affected by fluid in the body portion.

10. the method of claim 5, further comprising splitting, by a signal splitter of the passive sensor, the transmitted signal into the first portion and the second portion, the second portion defining the reference signal.

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UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 10,722,136 B2
APPLICATION NO. : 14/241179
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INVENTOR(S) : Chad E. Bouton

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

Column 10, Line 29, Claim 1, “through the body portion,” should read --through a body portion,--

Column 10, Line 40, Claim 1, “amplitude of resultant” should read --amplitude of the resultant--

Column 10, Line 62, Claim 2, “further configured to recieve” should read --further configured to receive--

Column 11, Line 9, Claim 5, “received, by a receiving antenna” should read --receiving, by a receiving antenna--

Column 11, Line 16, Claim 5, “combing, by a second circuit” should read --combining, by a second circuit--

Column 11, Line 18, Claim 5, “signal with resultant” should read --signal with the resultant--

Column 11, Line 22, Claim 5, “receiving, by the signal processor, transmitted output” should read --receiving, by a signal processor, the transmitted output--

Column 11, Line 27, Claim 5, “detecting, by signal processor” should read --detecting, by the signal processor--

Column 12, Line 22, Claim 8, “pulse of continuous wave” should read --sweep of continuous wave--

Signed and Sealed this
Eleventh Day of May, 2021



Drew Hirshfeld
*Performing the Functions and Duties of the
Under Secretary of Commerce for Intellectual Property and
Director of the United States Patent and Trademark Office*